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Stanford B. Hooker, Editor
NASA Goddard Space Flight Center, Greenbelt, Maryland

Elaine R. Firestone, Senior Scientific Technical Editor
Science Applications International Corporation, Beltsville, Maryland

Volume 26, New Laboratory Methods for Characterizing the Immersion Factors of Irradiance Sensors

Giuseppe Zibordi, Davide D'Alimonte, and Dirk van der Linde
JRC/Institute for Environment Sustainability, Ispra, Italy

Stanford B. Hooker
NASA Goddard Space Flight Center, Greenbelt, Maryland

James W. Brown
RSMAS University of Miami, Miami, Florida

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G. Zibordi, D. D'Alimonte, D. van der Linde, S.B. Hooker, and J.W. Brown

Abstract

The experimental determination of the immersion factor, $I_f(\lambda)$, of irradiance collectors is a requirement of any in-water radiometer. The eighth SeaWiFS Intercalibration Round-Robin Experiment (SIRREX-8) showed different implementations, at different laboratories, of the same $I_f(\lambda)$ measurement protocol. The different implementations make use of different setups, volumes, and water types. Consequently, they exhibit different accuracies and require different execution times for characterizing an irradiance sensor. In view of standardizing the characterization of $I_f(\lambda)$ values for in-water radiometers, together with an increase in the accuracy of methods and a decrease in the execution time, alternative methods are presented, and assessed versus the traditional method. The proposed new laboratory methods include: a) the continuous method, in which optical measurements taken with discrete water depths are substituted by continuous profiles created by removing the water from the water vessel at a constant flow rate (which significantly reduces the time required for the characterization of a single radiometer); and b) the Compact Portable Advanced Characterization Tank (ComPACT) method, in which the commonly used large tanks are replaced by a small water vessel, thereby allowing the determination of $I_f(\lambda)$ values with a small water volume, and more importantly, permitting $I_f(\lambda)$ characterizations with pure water. Intercomparisons between the continuous and the traditional method showed results within the variance of $I_f(\lambda)$ determinations. The use of the continuous method, however, showed a much shorter realization time. Intercomparisons between the ComPACT and the traditional method showed generally higher $I_f(\lambda)$ values for the former. This is in agreement with the generalized expectations of a reduction in scattering effects, because of the use of pure water with the ComPACT method versus the use of tap water with the traditional method.

Prologue

When an irradiance sensor is illuminated, the raw optical data at each wavelength, λ, are recorded as digitized voltages, $V(\lambda)$, in counts. Each sample is recorded at a specific time, t_i, which also sets the water depth, z. Raw irradiance data are typically converted to physical units using a calibration equation of the following form:

$$E_{\mathrm{cal}}(\lambda, t_i) = C_c(\lambda)\, I_f(\lambda)\, E(\lambda, t_i), \tag{1}$$

where $E_{\mathrm{cal}}(\lambda, t_i)$ is the calibrated irradiance, $C_c(\lambda)$ is the calibration coefficient (determined during the radiometric calibration of the sensor), $I_f(\lambda)$ is the so-called *immersion factor*†, and $E(\lambda, t_i)$ is the net signal detected by the radiometer while exposed to light.

In most cases,

$$E(\lambda, t_i) = V(\lambda, t_i) - \bar{D}(\lambda), \tag{2}$$

where $\bar{D}(\lambda)$ is the average bias or dark voltage measured during a special *dark cast* with the caps on the radiometer. In some cases, dark voltages are replaced by so-called *background* or *ambient* measurements, so illumination biases can be removed along with the dark correction. The latter is particularly important if the room where the experimental procedures are being conducted cannot be completely darkened.

† For the purposes of the calibration equation, the immersion factor for an above-water irradiance sensor is always equal to unity.

The immersion factor is a necessary part of the characterization of an in-water irradiance sensor, because when a cosine collector is immersed in water, its light transmissivity is less than it was in air. Irradiance sensors are calibrated in air, however, so a correction for this change in collector transmissivity must be applied when the in-water raw data are converted to physical units. The immersion must be determined experimentally, using a laboratory protocol, for each collector.

Studies of immersion effects date back to the work of Atkins and Poole (1933) who attempted to describe the internal and external reflection factors for an opal glass diffuser. To experimentally estimate these reflection contributions, they used a gas-filled lamp as a light source to vertically illuminate a diffuser at the bottom of a water vessel filled with varying depths of *distilled* water. Measurements were taken in air and in water, with distinctions (and corrections) made for *dry* and *wet* in-air measurements (the latter is distinguished from the former by a few millimeters of water on the diffuser). The in-water measurements were made in a *blackened* water vessel at a variety of depths using a protocol that recognized the importance of a water depth exceeding 0.9 times the radius of the diffuser. Based on many trials, a constant value of $I_f = 1.09$ was proposed for opal glass diffusers (the most popular diffuser material of the time).